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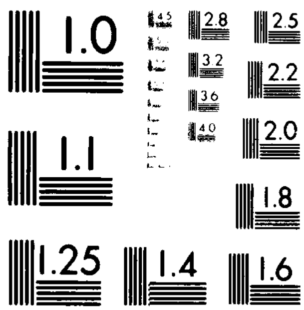

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Estimation of Wave Transmission Coefficients for Overtopping of Impermeable Breakwaters

by

(10) William N. Seelig

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COASTAL ENGINEERING TECHNICAL AID NO. 80-7

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Methods are presented for estimating coefficients of wave transmission by overtopping for smooth and rough impermeable breakwaters. These techniques can be used for monochromatic or irregular wave conditions and for submerged breakwaters. Example problems are worked to illustrate calculations.

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PREFACE

This report describes methods for estimating wave transmission coefficients for overtopping of impermeable breakwaters. It supplements Section 7.23 of the Shore Protection Manual (SPM) and replaces the Coastal Design Memorandum No. 76-1 (Seelig, 1976). The methods presented can be used with smooth or rough impermeable breakwaters and for irregular as well as monochromatic incident waves. Laboratory tests show that the prediction methods give useful estimates of transmission coefficients for submerged breakwaters. The work was carried out under the offshore breakwaters for shore stabilization program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by William N. Seelig, Hydraulic Engineer, under the general supervision of Dr. R.M. Sorensen, Chief, Coastal Processes and Structures Branch.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as suppl mented by Public Law 172, 88th Congress, approved 7 November 1963.

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

SYMBOLS AND DEFINITIONS

a, b	empirical coefficients of runup on rough breakwaters
B	crest width of a breakwater
C	an empirical wave transmission by overtopping coefficient
C_1, C_2, C_3	empirical smooth slope runup coefficients
d or d_s	water depth at the toe of the structure
F	breakwater freeboard = $h - d_s$
g	acceleration due to gravity
H or H_i	incident wave height; use the mean wave height for irregular waves
H_t	transmitted wave height
h	structure height
K_{To}	wave transmission by overtopping coefficient
L	wavelength
L_o	deepwater wavelength
R	wave runup
T	wave period; use the period of peak energy density for irregular waves
θ	breakwater seaward face front slope angle
ξ	the surf similarity parameter = $\tan \theta / \sqrt{H/L_o}$

ESTIMATION OF WAVE TRANSMISSION COEFFICIENTS
FOR OVERTOPPING OF IMPERMEABLE BREAKWATERS

by
William N. Seelig

I. INTRODUCTION

When a wave strikes an impermeable breakwater, some of the water may overtop the breakwater and produce regenerated waves. Section 7.233 of the Shore Protection Manual (SPM) (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977) and Seelig (1976) give a method for estimating transmission by overtopping coefficients for smooth, vertical-faced breakwaters overtopped by monochromatic waves. Wave period effects are not considered. This report presents a more general method of predicting transmission by overtopping coefficients that includes the influence of structure slope (nonvertical as well as vertical), crest width, roughness, wave period, and wave type (irregular and monochromatic waves). The method is based on laboratory tests for $d/gT^2 \leq 0.03$, where d is the water depth, g is the acceleration due to gravity, and T is the wave period. Figure 1 shows the case of transmission for an *impermeable* breakwater and illustrates some of the terms used. Methods described in this report apply to breakwaters with an impermeable surface, an impermeable core, or an impermeable diaphragm to prevent wave transmission through the structure.

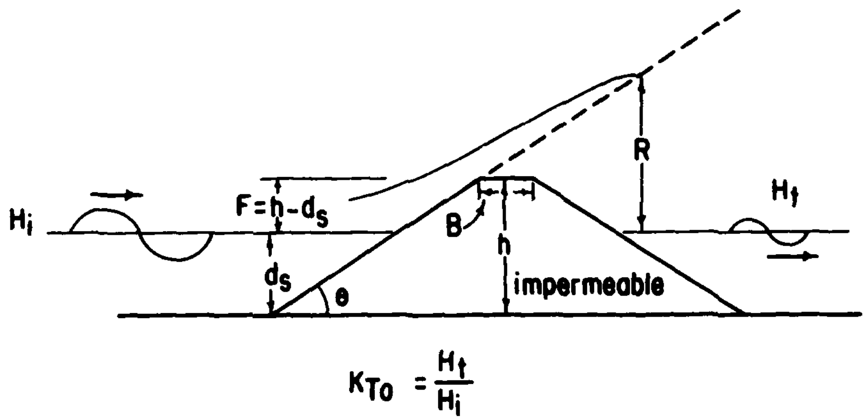


Figure 1. Wave transmission by overtopping of an impermeable breakwater.

II. ESTIMATION OF TRANSMISSION COEFFICIENTS

Laboratory data show that the coefficient of wave transmission by overtopping for an impermeable breakwater, K_{To}, can be predicted using (Seelig, 1980).

$$K_{To} = \frac{H_t}{H_i} = C\left(1 - \frac{F}{R}\right) \quad (1)$$

where F/R is the ratio of the breakwater freeboard to wave runup suggested by Cross and Sollitt (1971), and C is the empirical given by

$$C = 0.51 - 0.11 \frac{B}{h} \tag{2}$$

where B is the structure crest width and h the structure height. Equation (2) is valid for the range $0 \leq B/h \leq 3.2$. Equation (1) slightly underpredicts the transmission coefficient for submerged breakwaters with a 1 on 15 bottom slope in front of the breakwater; a revised formula is suggested for those cases:

$$K_{To} = C\left(1 - \frac{F}{R}\right) - \left(1 - 2C\right)\frac{F}{R} \tag{3}$$

III. ESTIMATION OF WAVE RUNUP

Values of wave runup on the structure are necessary to use equation (1). If the runup exceeds the breakwater freeboard, transmission by overtopping will occur. The recommended runup equation for smooth slopes is given by Franzius (1965)

$$R = HC_1\left(0.123 \frac{L}{H}\right)^{\left(C_2 \sqrt{H/d} + C_3\right)} \tag{4}$$

where

H or H_i	=	incident wave height
L	=	wavelength
d	=	water depth
C_1, C_2, and C_3	=	empirical coefficients.

Values of the empirical coefficients are given in Table 1. A linear interpolation of these values is necessary to obtain coefficients for other slopes.

Table 1. Empirical wave runup prediction coefficients for smooth impermeable slopes.

Front-face slope of breakwater	C_1	C_2	C_3
Vertical	0.958	0.228	0.0578
1 on 0.5	1.280	0.390	-0.091
1 on 1.0	1.469	0.346	-0.105
1 on 1.5	1.991	0.498	-0.185
1 on 2.25	1.811	0.469	-0.080
1 on 3.0	1.366	0.512	0.040

The recommended equation for estimating runup on rough slope impermeable breakwaters is given by Ahrens and McCartney (1975):

$$R = \left(\frac{a\xi}{1 + b\xi}\right)H; \quad \xi = \frac{\tan\theta}{\sqrt{H/L_o}} \tag{5}$$

where ξ is the surf parameter, θ the angle of the seaward face of the breakwater, L_o the deepwater wavelength given from linear theory as

$$L_o = \frac{g\,T^2}{2\pi} \tag{6}$$

and a and b are empirical coefficients. Suggested values of a and b are in Table 2.

Table 2. Rough slope empirical runup coefficients for breakwaters with $1.25 \le \cot\theta \le 5.0$.

Armor type	a	b	Comment
Two layers of rubble	0.692	0.504	Recommended
Two layers of rubble	0.956	0.398	To obtain an upper limit or conservative estimate of runup and K_{To}
Two layers of dolos	0.988	0.703	

For additional information on wave runup refer to Stoa (1978) and the SPM.

For irregular wave conditions use the mean wave height (approximately 0.63 times the significant wave height; Sec. 3.22 of the SPM) and the period of peak energy density in equations (4), (5), and (6) (Seelig, 1980).

IV. EXAMPLE PROBLEMS

* * * * * * * * * * * * * * * EXAMPLE PROBLEM 1 * * * * * * * * * * * * * * *

GIVEN: A rough impermeable breakwater covered with two layers of rubble on a 1 on 3 slope. The structure height is 18 feet (5.49 meters), crest width is 12 feet (3.66 meters), and water depth is 15 feet (4.57 meters).

FIND: The transmitted wave height produced by overtopping for an incident wave with a height of 9 feet (2.74 meters) and period of 11 seconds.

SOLUTION: From equation (5) the surf parameter is

$$\xi = \frac{\tan\theta}{\sqrt{H/L_o}} = \frac{0.333}{\sqrt{9/(5.12 \times 11^2)}} = 2.77$$

Using the recommended rubble runup coefficients of a = 0.692 and b = 0.504 (Table 2), the predicted runup is:

$$R = \left(\frac{0.692\xi}{1+0.504\xi}\right) H = \left(\frac{0.692 \times 2.77}{1+0.504 \times 2.77}\right) \times 9 = 7.2 \text{ feet } (2.2 \text{ meters})$$

The breakwater freeboard, F, is $h - d_s = 18 - 15 = 3.0$ feet (0.91 meter). From equation (2), $C = 0.51 - 0.11\,B/h = 0.51 - 0.11\,(12/18) = 0.44$ and from equation (1), the transmission coefficient is:

$$K_{To} = C\left(1 - \frac{F}{R}\right) = 0.44\left(1 - \frac{3.0}{7.2}\right) = 0.257$$

The transmitted wave height is:

$$H_t = K_{To}\,H_i = 0.257\ (9) = 2.3 \text{ feet } (0.71 \text{ meter})$$

* * * * * * * * * * * * * * * EXAMPLE PROBLEM 2 * * * * * * * * * * * * * * *

GIVEN: A vertical, smooth-faced impermeable breakwater with a crest width of 12.0 feet (3.7 meters), a structure height of 16.0 feet (4.9 meters), and a water depth of 11.2 feet (3.4 meters) as shown in Figure 2(a).

FIND: Transmitted wave height for an incident monochromatic wave with a period of 12.0 seconds and height of 6.0 feet (1.8 meters).

SOLUTION: From equation (4) the runup is

$$R = 6\ (0.958)\left(0.123\ \frac{224.1}{6}\right)^{\left(0.228\sqrt{6/11.2}\ +\ 0.0578\right)} = 8.1 \text{ feet } (2.5 \text{ meters})$$

From equation (2)

$$C = 0.51 - 0.11\left(\frac{12.0}{16.0}\right) = 0.43$$

and the breakwater freeboard is

$$F = h - d_s = 16.0 - 11.2 = 4.8 \text{ feet } (1.5 \text{ meters})$$

From equation (1) the transmission by overtopping coefficient is

$$K_{To} = C\left(1 - \frac{F}{R}\right) = 0.43\left(1 - \frac{4.8}{8.1}\right) = 0.175$$

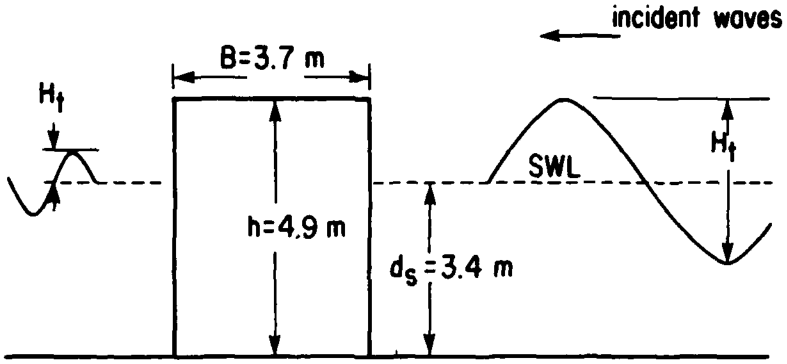
and the transmitted wave height is

$$H_t = K_{To}\,H = 0.175 \times 6.0 = 1.0 \text{ foot } (0.32 \text{ meter})$$

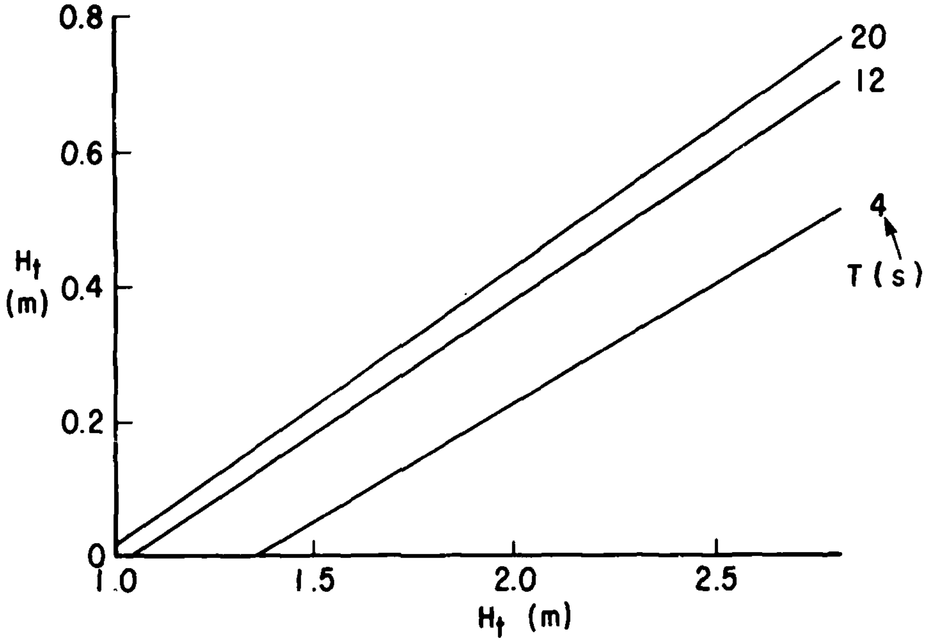
Figure 2(b) shows how the predicted transmitted wave height varies as a function of incident wave height and period for this example breakwater.

V. SUMMARY

Methods of predicting transmission coefficients of impermeable breakwaters show that the magnitude of the transmission coefficients is a function of the breakwater freeboard, incident wave height and period, water depth, and structure slope, crest width and roughness. Calculations may be performed manually or with the FORTRAN computer program OVER (Program No. 752XR1CYO) available from the CERC ADP Coordinator, U.S. Army Coastal Engineering Research Center, Fort Belvoir, Virginia 22060.



a. Profile view of conditions for Example 2.



b. Predicted transmitted wave heights.

Figure 2. Predicted transmitted wave heights for Example 2.

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